

How to make the wavelength calibration file for OES

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Run a script that generates raw extracted spectrum for each order, which is useful for line identification

`./genrawcompdata.py`

```
#!/Users/edermartioli/Ureka/variants/common/bin/python
import sys, os

begredcommand = '/Users/edermartioli/opera-1.0//bin/operaWavelengthCalibrationTool --
outputWaveFile=/Users/edermartioli/Reductions/OES//thar-lines/OEStest.wcar.gz --inputGeomFile=/
Users/edermartioli/Reductions/OES/2013-07-04/2013-07-04_OESBLADE_100kHz.geom.gz --
uncalibrated_spectrum=/Users/edermartioli/Reductions/OES/
2013-07-04/2013-07-04_OESBLADE_100kHz_comp.e.gz --inputWaveFile=/Users/edermartioli/opera-1.0/
DefaultCalibration/OES/OES_wcal_ref.dat.gz --uncalibrated_linewidth=1.6 --atlas_lines=/Users/
edermartioli/opera-1.0//config/thar_MM201006.dat.gz --atlas_spectrum=/Users/edermartioli/opera-1.0//
config/LovisPepe_ThArAtlas.dat.gz --parseSolution=0 --ParRangeSizeInPerCent=0.1 --NpointsPerPar=10
--maxNIter=40 --minNumberOfLines=40 --maxorderofpolynomial=4 --dampingFactor=0.85 --
initialAcceptableMismatch=1.5 --nsigclip=2.25 --normalizeUncalibratedSpectrum=0 --
normalizationBinSize=180 --LocalMaxFilterWidth=6 --ordernumber='

for i in range(28,81) :
    outputfile = 'OES_ord%.1d.dat'%i
    command = begredcommand + str(i) + ' > ' + outputfile
    print command
    os.system(command)
```

Note: It uses a first guess for wavelength solution, which is given in file:

`--inputWaveFile=/Users/edermartioli/opera-1.0/DefaultCalibration/OES/OES_wcal_ref.dat.gz`

Files used for Th-Ar lines identification

Th-Ar atlas:

LovisPepe_ThArAtlas.dat

../head LovisPepe_ThArAtlas.dat

wavelength
(Angstroms)

Intensity

3033.0867480159	103.99224526863826	0.36633407377209	0.36633407377209	97.132933537024
3033.1044532706	13.99105352402549	0.32747877953964	0.32747877953964	185.25330455497
3033.1221586285	8.59002753307328	0.29539838851394	0.29539838851394	184.28998378133
3033.1398640899	12.32197084022707	0.28943599056281	0.28943599056281	183.67802915977
3033.1575696546	15.15462980473967	0.30093380311459	0.30093380311459	183.35515689535

Th-Ar observed spectrum:

OES_ord36.dat
OES_ord37.dat
OES_ord38.dat
...

../head OES_ord36.dat

wavelength (nm)

**only good if first
solution is near
correct solution!**

distance (pixel)

Intensity

782.935	0.403275	3083.38
782.94	1.22487	3049.62
782.945	2.04644	2907.25
782.949	2.868	2905.38
782.954	3.68955	2984
782.959	4.51107	3081.88
782.964	5.33258	3174.75
782.968	6.15407	3217.88
782.973	6.97555	3643.38

How to identify ThAr Lines?

The goal is to produce the file: **OES_ThArLines.dat**

which contains the following:

```
# E. Martioli, LNA -- Dec 14 2015
# List of Th-Ar lines identified manually
# The reference Th-Ar spectrum is LovisPepe_ThArAtlas.dat
#
# ordernumber wavelength[nm] distance[pix]
```

36	767.007	32.8728
36	767.620	120.712
36	768.529	251.724
36	770.480	538.605
36	771.392	676.610
36	774.257	1124.19
36	777.195	1612.57
36	778.230	1793.12
36	778.894	1911.26
36	779.313	1987.39
36	779.542	2029.40

**order
number**

**line wavelength
position (nm)**

**line distance
position (pixel)**

**line wavelength
position (nm)**



Must be measured from Atlas, i.e. column #1 divided by 10.0 (to convert to nm) in file "LovisPepe_ThArAtlas.dat".

**line distance
position (pixel)**



Must be measured from an extracted Th-Ar spectrum, i.e., column #2 in file "OES_ord36.dat".

Example on how to perform line measurements

Open two terminal windows

Go to data directory in both terminals

```
cd /Users/edermartoli/Reductions/OES/thar-lines
```

Open **gnuplot** in both terminals

```
gnuplot
```

```
G N U P L O T
Version 4.4 patchlevel 4
last modified November 2011
System: Darwin 14.3.0
```

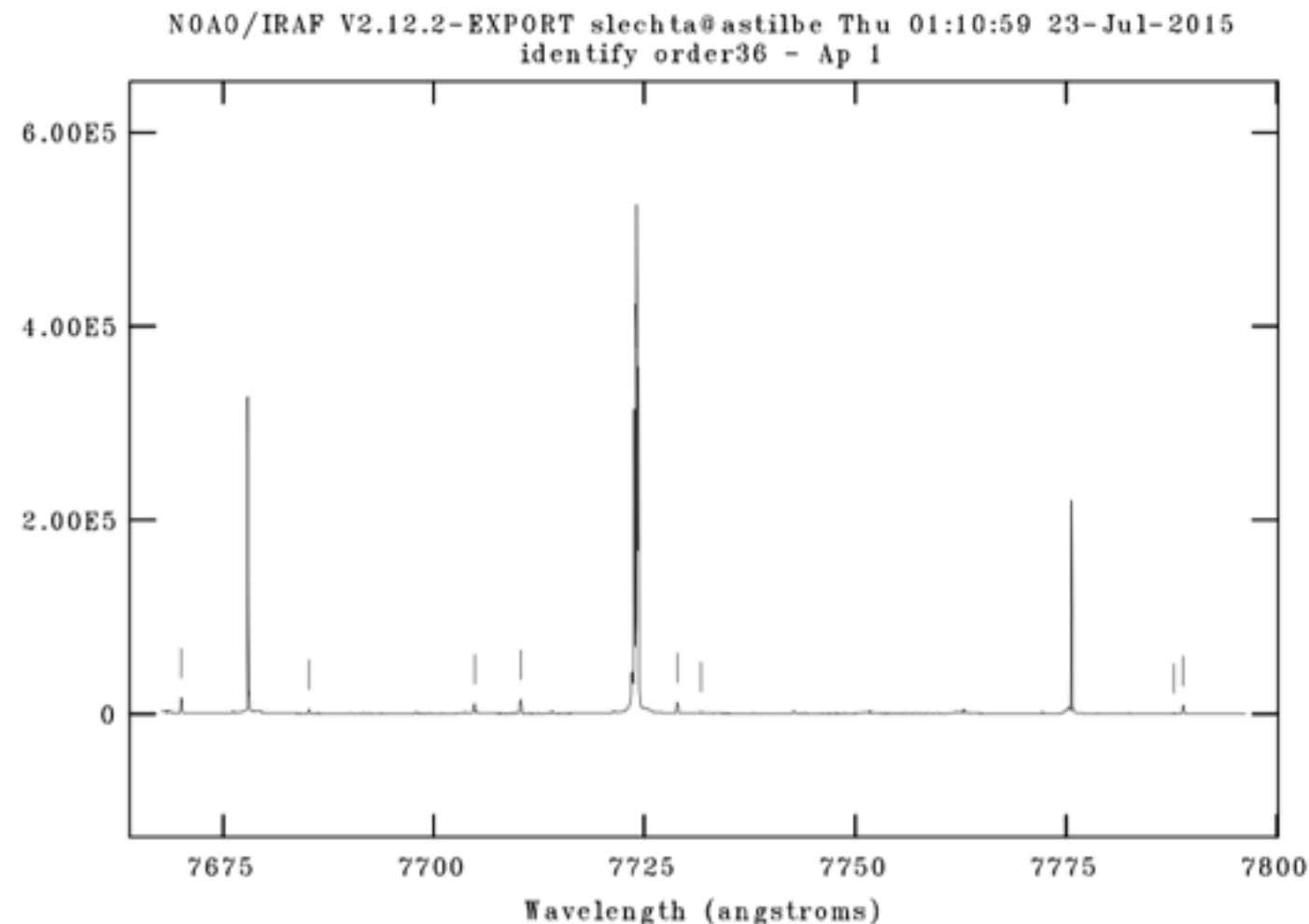
```
Copyright (C) 1986-1993, 1998, 2004, 2007-2011
Thomas Williams, Colin Kelley and many others
```

```
gnuplot home:      http://www.gnuplot.info
faq, bugs, etc:    type "help seeking-assistance"
immediate help:    type "help"
plot window:       hit 'h'
```

```
Terminal type set to 'x11'
gnuplot>
```

Check wavelength range for a given order

Tip: use previous identification that you did in IRAF!



For example, for order # 36 the wavelength range is approximately:

767.0 to 780.0

Go to one of the gnuplot windows, then set x range to the order wavelength range and then plot the Atlas spectrum:

```
gnuplot> set xrange[767.0:780.0]  
gnuplot> plot 'LovisPepe_ThArAtlas.dat' u ($1/10):2 w l
```

Tip: use mouse right click to zoom in.

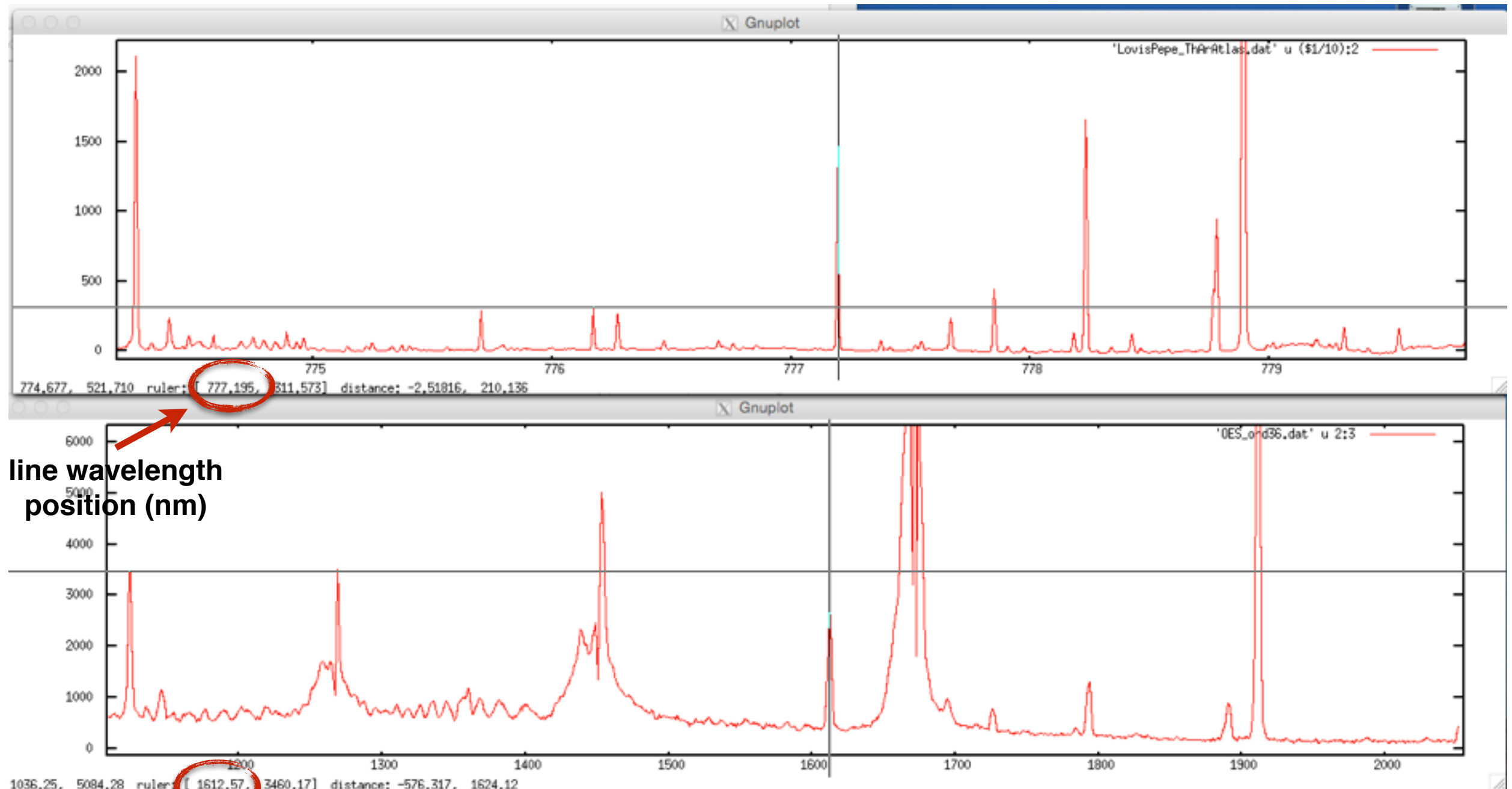
Then go to the other gnuplot window and plot Th-Ar observed spectrum of that respective order:

```
gnuplot> plot 'OES_ord36.dat' u 2:3 w l
```

Align and adjust the two windows so one can see the two spectra together and be able to identify lines

1. Zoom in selected parts of the spectrum.
2. Identify lines that are present on both the Atlas and the extracted spectrum.
3. Perform measurements of line positions for lines lying over the entire range of each order. Make sure it's well sampled, i.e. take more or less **one measurement every 1 nm**. It's important to measure lines near the edges of each order, i.e., at the beginning and start of each order.
4. For performing measurements, one can use the key "R" in gnuplot for fixing a cursor position, which will be marked with a crossed-hair line and will show the coordinates at the bottom (see next slide for visual example).

Measurement Example:



line wavelength
position (nm)

line distance
position (pixel)

I usually write down
the measurements
and then type them
later into file
OES_ThArLines.dat.

edu 36		
767.007	32.8728	
767.620	120.712	
768.529	251.729	
770.410	539.605	
771.342	678.61	
774.252	1124.19	
777.195	1612.57	
778.230	1793.12	
778.899	1911.26	
779.313	1981.19	
779.592	2029.10	

The final file with measurements for 2 orders
(order # 36 and 37) looks like this:

```
# E. Martioli, LNA -- Dec 14 2015
# List of Th-Ar lines identified manually
# The reference Th-Ar spectrum is LovisPepe_ThArAtlas.dat
#
# ordernumber wavelength[nm] distance[pix]
#
36 767.007 32.8728
36 767.620 120.712
36 768.529 251.724
36 770.480 538.605
36 771.392 676.610
36 774.257 1124.19
36 777.195 1612.57
36 778.230 1793.12
36 778.894 1911.26
36 779.313 1987.39
36 779.542 2029.40
37 750.849 56.0589
37 751.042 84.3740
37 752.551 306.509
37 754.931 668.225
37 756.768 959.340
37 758.571 1255.44
37 759.818 1466.14
37 761.835 1822.08
37 762.718 1984.26
```

How to test it?

Run wavelength calibration for orders to be tested:

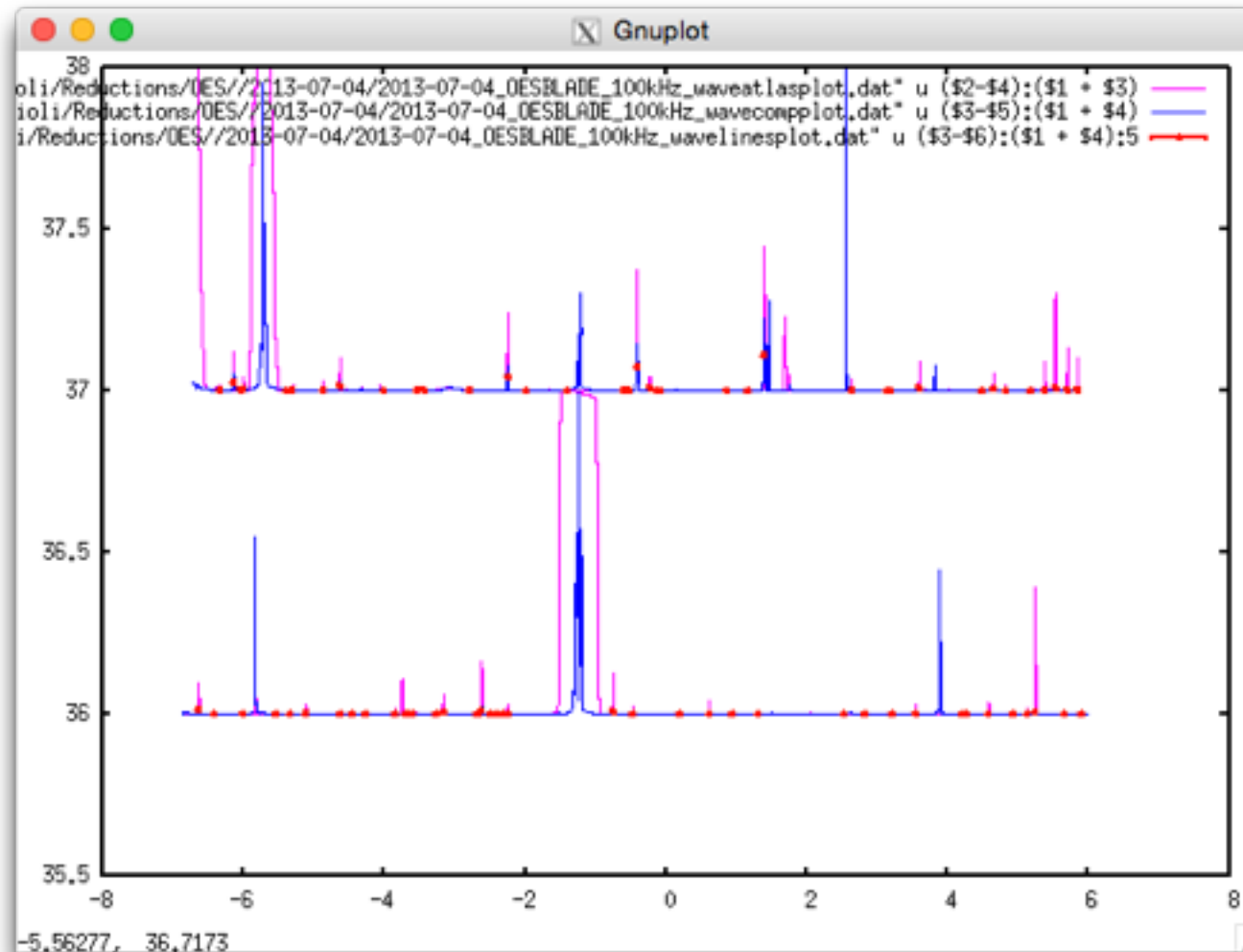
```
/Users/edermartoli/opera-1.0//bin/operaWavelengthCalibration --outputWaveFile=/Users/
edermartoli/Reductions/OES//2013-07-04/2013-07-04_OESBLADE_100kHz.wcal.gz --inputGeomFile=/
Users/edermartoli/Reductions/OES//2013-07-04/2013-07-04_OESBLADE_100kHz.geom.gz --
uncalibrated_spectrum=/Users/edermartoli/Reductions/OES//
2013-07-04/2013-07-04_OESBLADE_100kHz_comp.e.gz --inputLineSetFilename=/Users/edermartoli/
opera-1.0//DefaultCalibration/OES/OES_ThArLines.dat --uncalibrated_linewidth=1.6 --
atlas_lines=/Users/edermartoli/opera-1.0//config/thar_MM201006.dat.gz --atlas_spectrum=/
Users/edermartoli/opera-1.0//config/LovisPepe_ThArAtlas.dat.gz --parseSolution=0 --
ParRangeSizeInPerCent=2 --NpointsPerPar=1000 --maxNIter=40 --minNumberOfLines=40 --
maxorderofpolynomial=5 --dampingFactor=0.9 --initialAcceptableMismatch=2.0 --nsigclip=2.25
--normalizeUncalibratedSpectrum=0 --normalizationBinSize=100 --LocalMaxFilterWidth=5 --
DetectionThreshold=0.05 --MinPeakDepth=1.0 --ordersplotfilename=/Users/edermartoli/
Reductions/OES//2013-07-04/2013-07-04_OESBLADE_100kHz_waveordsplot.eps --specplotfilename=/
Users/edermartoli/Reductions/OES//2013-07-04/2013-07-04_OESBLADE_100kHz_wavespecplot.eps --
ordersscriptfilename=/Users/edermartoli/Reductions/OES//
2013-07-04/2013-07-04_OESBLADE_100kHz_waveordplot.gnu --specscriptfilename=/Users/
edermartoli/Reductions/OES//2013-07-04/2013-07-04_OESBLADE_100kHz_wavespecplot.gnu --
ordersdatafilename=/Users/edermartoli/Reductions/OES//
2013-07-04/2013-07-04_OESBLADE_100kHz_waveordsplot.dat --atlasdatafilename=/Users/
edermartoli/Reductions/OES//2013-07-04/2013-07-04_OESBLADE_100kHz_waveatlasplot.dat --
compdatafilename=/Users/edermartoli/Reductions/OES//
2013-07-04/2013-07-04_OESBLADE_100kHz_wavecompplot.dat --linesdatafilename=/Users/
edermartoli/Reductions/OES//2013-07-04/2013-07-04_OESBLADE_100kHz_wavelinesplot.dat --
verbose --minorder=36 --maxorder=37
```

How to test it?

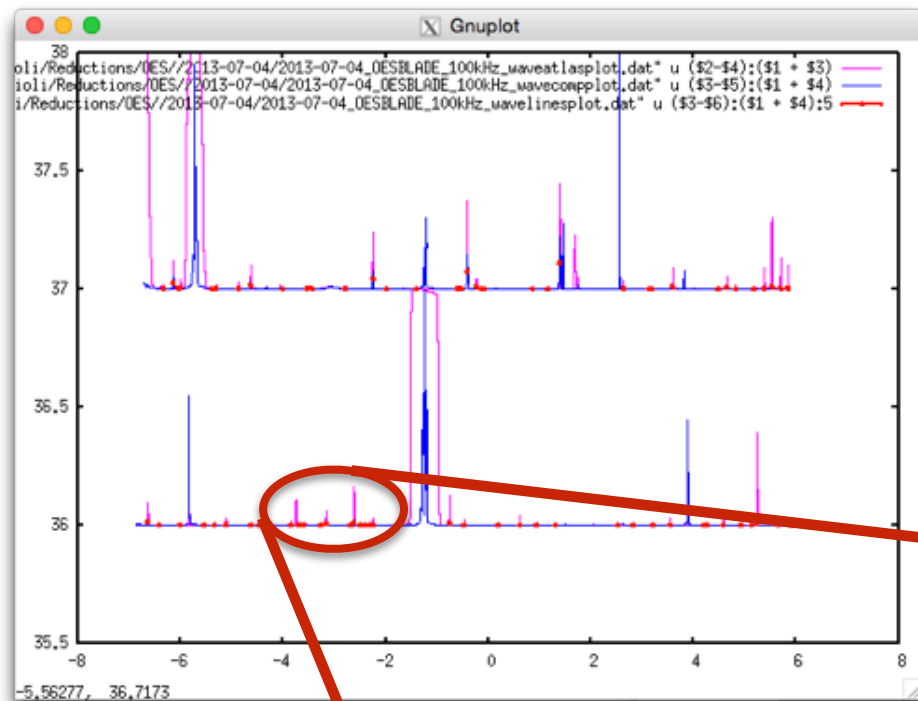
Then one can grab the gnuplot command from the gnuplot script (*.gnu) generated by the module, and use this to plot both the atlas and the observed Th-Ar spectrum together, and also the lines selected by the module to perform wavelength calibration.

```
$ grep plot 2013-07-04_OESBLADE_100kHz_wavespecplot.gnu
```

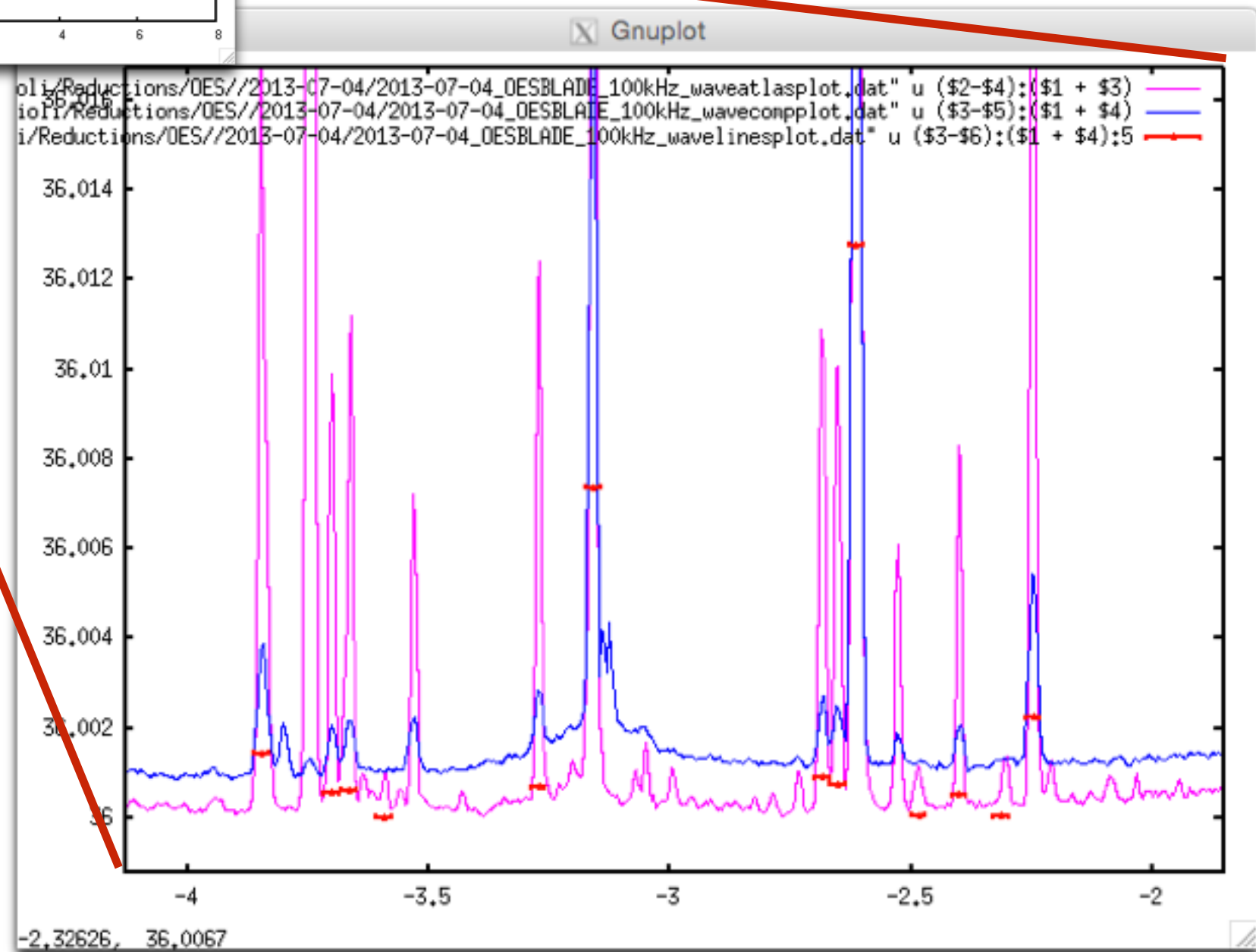
```
gnuplot> plot "/Users/edermartioli/Reductions/OES//  
2013-07-04/2013-07-04_OESBLADE_100kHz_waveatlasplot.dat" u ($2-$4):($1 + $3) w l lt 4, "/  
Users/edermartioli/Reductions/OES//2013-07-04/2013-07-04_OESBLADE_100kHz_wavecompplot.dat" u  
($3-$5):($1 + $4) w l lt 3, "/Users/edermartioli/Reductions/OES//  
2013-07-04/2013-07-04_OESBLADE_100kHz_wavelinesplot.dat" u ($3-$6):($1 + $4):5 w xerr pt 7 lw  
2 lt 1
```



Zoom in and check if the two spectra are matching...



Note that the blue line is the extracted Th-Ar spectrum observed with OES and the pink line is the Th-Ar atlas spectrum. The red points with error bars show the spectral lines identified by OPERA automatically. Blue spectrum is already using the final pixel-to-wavelength solution, therefore it should match the same line positions as in the pink spectrum.



Troubleshooting...

What to do if things don't look good?

Let's say the atlas and the observed spectra are not matching, what could have gone wrong?

There are a few things that happened to me before that can be checked...

- A single misleading line could cause issues with the calibration, so make sure all lines are identified. It's better to not have a line than having a doubtful one.
- It could be missing lines at the beginning or end of an order
- Poor sampling. Usually it's not a big concern but sometimes a large gap can cause issues
- If nothing works it's probably easier to redo the line identification than spending time troubleshooting

```
/Users/edermartoli/opera-1.0/pipeline/py0ES/operaoes.py --  
night=2013-07-04 --datarootdir=/data/0ES/ --pipelinehomedir=/Users/  
edermartoli/opera-1.0/ --productrootdir=/Users/edermartoli/  
Reductions/0ES/ --product=CALIB -pvt
```